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Energy situation and renewables in Turkey and environmental effects of energy use

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Abstract

The effects on global and environmental air quality of pollutants released into the atmosphere from fossil fuels in power plants provide strong arguments for the development of renewable energy resources. Clean, domestic and renewable energy is commonly accepted as the key for future life, not only for Turkey but also for the world. In this regard, the objective of this paper is to present a review of the energy situation, technical and economical potential and utilization of renewables, including hydraulic energy, biomass energy, solar energy, wind energy and geothermal energy, in Turkey and then concerned with greenhouse gas emissions status, especially in air pollution, and environmental impacts of renewable energy sources. The renewable energy potential of the country, their present utilization, and greenhouse gas emissions status are evaluated based on the available data. The present paper shows that there is an important potential for renewables in Turkey and making use of renewable energy and energy efficiency resources to provide energy services to the electricity consumers can provide significant environmental benefits for Turkey.

Keywords: Energy resources; Environment; Turkey

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1. Introduction

A popular (and quite accurate) conception of energy is that it is a resource that makes life easier for us—a resource that takes us from one place to another, provides heat and light, powers our entertainment devices and labor-saving appliances, and improves our quality of life. To understand just what energy is, it is useful to look first at the many forms in which it comes. Primary energy resources on the earth include fossil fuels (petroleum, natural gas, and coal), nuclear energy, and renewables such as solar, wind, hydropower, geothermal, and biomass [1]. Fossil fuels and nuclear energy sources are fundamentally limited and exhaustible. As these sources become depleted, human beings will be forced to learn how to evaluate renewable energy sources.

The effects on global and environmental air quality of pollutants released into the atmosphere from fossil fuels in power plants provide strong arguments for the development of renewable energy resources. Clean, domestic and renewable energy is commonly accepted as the key for future life, not only for Turkey but also for the world. The consumption of conventional fossil energy sources (coal, petroleum and natural gas) on one hand results in serious environmental pollution problems, and on the other hand faces with the danger of exhaustion. In order to have a sustainable development in Turkey, it must be enhanced the efficiency of the conventional energy generation and increased the proportion of renewable energy sources in the total energy budget.

In this paper, energy situation and major environmental impacts of energy utilization in Turkey, especially greenhouse gas emissions, are analysed; renewable energy sources including hydropower, biomass, solar, wind and geothermal energy are examined with respect to their potential and current use.

2. Energy situation in Turkey

Although Turkey has almost all kinds of energy resources, it is an energy importing country; more than half of the energy requirement has been supplied by imports. Therefore, it seems that if the country wants to supply its demand by domestic and clean energy resources, the transition to renewable energy resources must be realized in a reasonable time period [2]. When it is examined energy consumption data of Turkey, it is realized that oil has the biggest share in total primary energy consumption. The high level of dependence on imported petroleum and natural gas is the dominant factor in Turkey's pattern of energy consumption. While the share of petroleum in consumption of commercial primary energy increase 3.5% from 2003 to 2004, the share of natural gas in consumption of commercial primary energy grow 5% from 2003 to 2004.

Turkey's primary energy sources include hydropower, geothermal, lignite, hard coal, oil, natural gas, wood, animal and plant wastes, solar and wind energy. In 2004, primary energy production and consumption has reached 24.332 million tonnes (Mt) of oil equivalent (Mtoe) and 86.20 Mtoe, respectively. Table 1 shows the Turkey's primary energy consumption and production in 2003 and 2004. Fossil fuels provided about 87.5% of the total energy consumption of the year 2004, with oil (38.2%) in first place, followed by coal (25.6%) and natural gas (23.7%). Turkey has not utilized nuclear energy yet. The Turkish coal sector, which includes hard coal as well as lignite, accounts for nearly one half of the country's total primary energy production, with lignite being the main domestic energy source at 9.141 Mtoe in 2004. The renewables collectively provided 12.5% of the primary energy, mostly in the form of combustible renewables and wastes (6.4%), hydropower (about 4.6%), geothermal (1.0%), and much less by other renewable energy resources (approximately 0.5%) [3].

An historical summary of installed electricity generating capacity in Turkey is shown in Table 2. Net electricity generation in Turkey has more than doubled over the past decade,

Table 1
Turkey's primary energy production and consumption (Mtoe) [3]

Energy source	Production		Consumption		Increase (2003–2004) in consumption
	2003-year	2004-year	2003-year	2004-year	Percentage
Fossil fuels	13.782	13.566	72.072	75.434	+4.7
Oil	2.494	2.390	31.806	32.922	+3.5
Natural gas	0.511	0.644	19.450	20.426	+5.0
Coal	10.777	10.532	20.816	22.086	+6.1
Nuclear	–	–	–	–	–
Renewables	10.001	10.766	10.001	10.766	+7.7
Hydro	3.038	3.963	3.038	3.963	+30.4
Geothermal	0.860	0.891	0.860	0.891	+3.6
Solar	0.350	0.375	0.350	0.375	+7.1
Wind	0.005	0.005	0.005	0.005	0
Comb. renew. and wastes	5.748	5.532	5.748	5.532	−3.9
Total	23.783	24.332	82.073	86.200	+5.0

Table 2
Installed electric energy generation capacity as primary energy sources in Turkey (MW) [3]

Source	Years						
	1970	1980	1990	2000	2003	2004	2005*
Total thermal	1509.5	2987.9	9535.8	16052.5	22974.4	24144.7	25878.7
Hard coal	350.3	323.3	331.6	480.0	1800.0	1845.0	1986.0
Lignite	290.9	1047.0	4874.1	6508.9	6438.9	6450.8	7130.8
Oil	837.4	1421.1	1747.8	1585.6	2733.2	2569.2	2527.7
Natural gas	5.2	12.4	2210.0	4928.3	8889.4	10158.8	11118.7
With multi fuels	25.7	184.1	372.3	2549.7	3112.9	3120.9	3115.5
Geothermal	–	–	17.5	17.5	15.0	15.0	15.0
Wind	–	–	–	18.9	18.9	18.9	20.1
Hydraulic	725.4	2130.8	6764.3	11175.2	12578.7	12645.4	12906.1
Nuclear	–	–	–	–	–	–	–
Total capacity	2234.9	5118.7	16317.6	27264.1	35587.0	36824.0	38819.9

*Provisional.

Table 3
Electric energy generation as primary energy sources in Turkey (GW h) [3]

Source	Years						
	1970	1980	1990	2000	2003	2004	2005*
Total thermal	5590.2	11927.2	34315.3	93934.2	105101.0	104463.7	122174.0
Hard coal	1382.3	911.7	620.8	3819.0	8663.0	11998.1	13057.9
Lignite	1442.2	5048.6	19560.5	34367.3	23589.9	22449.5	30008.0
Oil	2600.0	5831.2	3941.7	9310.8	9196.2	7670.3	8016.2
Natural gas	165.7	135.7	10192.3	46437.1	63651.9	62345.8	71091.9
Geothermal	–	–	80.1	75.5	88.6	93.2	94.6
Wind	–	–	–	33.4	61.4	57.7	56.6
Hydraulic	3032.8	11348.2	23147.6	30878.5	35329.5	46083.7	39658.1
Nuclear	–	–	–	–	–	–	–
Total generation	8623.0	23275.4	57543.0	124921.6	140580.5	150698.3	161983.3

*Provisional.

but it is not sufficient to keep up with expected demand. As a result, Turkey is importing electricity, and signed an agreement with its neighbour, Bulgaria, which will allow Turkey to purchase 33.7 billion kW h of electricity over the 10-year period from 1999 to 2009. This deal has had implications for future power plant construction planning, because import of electricity from Bulgaria, at 3–3.5 cents/kW h, is actually cheaper than the incremental cost of producing electricity from a new thermal-electric power plant (about 5 cents/kW h) [4].

Table 3 shows electricity production from thermal and hydropower sources in Turkey by years. At the end of 2004, hydropower and thermal power plants reached 36 824 GW, the share of thermal has increased to 65.6% of which 22.5% lignite and hard coal, 8.5% with multi-fuels, 7.0% fuel-oil and diesel oil, and 27.6% natural gas, while that of hydro had

fallen to 34.34%. In 2005, installed capacity rose to 38 819.9 GW. Most thermal capacity was fuel oil fired power plant until the beginning of 1980, when lignite plants took the lead. In the second half of the 1980s, natural gas fired plants were increasingly used and became second only to lignite by 1990. In 2005, 161.98 TW h of electricity, the basic input for the economy and industry, was generated of which 75.5% from thermal and 24.5% from hydrosources.

3. Renewables in Turkey

National and international bodies use a variety of definitions for renewable energy. The renewable energy working party of International Energy Agency set down the following definitions: "Renewable energy is energy that derived from natural processes that are replenished constantly. In its various form the sun, or from heat generated deep within the Earth. Included in the definition is energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, and biofuels and hydrogen derived from renewable resources" [5].

Turkey has substantial reserves of renewable energy resources. Renewables make the second-largest contribution to domestic energy production after coal. In 2004, renewable energy production represented about 10.766 Mtoe (44.25% of total generation). More than half of renewables used in Turkey are composed of combustible renewables and waste, the rest being mainly hydro (36.8%) and geothermal (8.3%) [3]. Combustible renewables and waste used in Turkey are almost exclusively non-commercial fuels, typically wood and animal products, used in the residential sector for heating. The use of biomass for residential heating, however, has declined owing to replacement of non-commercial fuels by commercial fuels. The contribution of wind and solar is still small but is expected to increase [6].

In 2005, the total electricity generation from renewables is 39.84 TW h and the share of the renewables given by 24.6%. In 1990, generation from renewables was 23.2 TW h and their share in power generation was higher, representing 40.4%. Hydro is the dominant source of renewable electricity, with only 0.28 TW h derived from other sources. Hydro production fluctuates annually depending on the weather.

Renewable energy technologies produce marketable energy by converting natural phenomena/resources into useful energy form. These resources represent a massive energy potential, which greatly exceeds that of fossil fuel resources. The usage of renewable energy resources is a promising prospect for the future as an alternative to conventional energy. However, except biomass energy, the proportion of other renewable energy used is still much smaller than that of the conventional energy resources [7].

The following sections represent potential and utilization of various renewable energies used in Turkey in recent years.

3.1. Hydropower

There is a general view that hydroelectricity is the renewable energy source par excellence, non-exhaustible, non-polluting, and more economically attractive than other options. And although the number of hydropower plants that can be built is finite, only a third of the sites quantified as economically feasible are tapped. Most renewable sources of energy hydroelectricity generation are capital intensive but have lower operational costs

than thermal and nuclear options. The high initial cost is a serious barrier for its growth in developing countries where most of the untapped economic potential is located [8].

Hydropower is obtained by allowing water to fall on a turbine to turn a shaft. Electricity is produced from the kinetic energy of falling water. The requirement for a hydropower site are a river with a reliable flow of water in a canyon with high walls and a narrow spot at which a dam can be built [9].

The gross hydroelectric power potential depends on the foreseen development projects of the region. For Turkey, it are estimated as 433–442 TW h/yr [10] that is equal to 1% of the total hydropower potential of the world (Table 4) and 14% of European hydropower potential [11]. Technical hydroelectric power potential corresponds to the technically available part of the gross potential. For example a permeable geological formation will promote a decrease in the available potential. It can slightly increase with developing technologic possibilities. Almost half of the gross potential is technically exploitable. The technical hydroelectric potential of Turkey are estimated as 216 TW h/yr. Economic hydroelectric power potential corresponds to the economically advantageous part of the technical potential, compared with alternative energy resources [12]. Economic hydroelectric power potential of Turkey is 129.9 TW h/yr by the end of February 2006 and 35.4% of this potential in operation while 8.1% and 56.5% of total potential are under construction and in various design level, respectively.

According to findings of a study in which a new criterion is developed related to key concept of "the economical feasibility", by taking into consideration some undervalued and even ignored benefits of hydro plants and some overvalued benefits of thermal power plants, economically feasible hydropower potential goes up 188 TW h/yr, with an increase ratio of 47% compared to General Directorate of State Hydraulic Works (DSI) value [13,14]. Turkey's hydropower potential according to DSI and the new developed criteria together with installed power values are given in Table 5.

As of February 2006, there were 142 hydro plants in operation. These have a total installed capacity of 12 788 MW and an annual average generation capacity of 45 930 GW h, amounting to almost 35.4% of the total exploitable potential, which is

Table 4
Hydropotential of Turkey compared to world's potential [10]

Region	Gross theoretical hydroelectric potential (GW h/yr)	Technically feasible hydroelectric potential (GW h/yr)	Economically feasible hydroelectric potential (GW h/yr)
Africa	4 000 000	1 665 000	1 000 000
Asia	19 000 000	6 800 000	3 600 000
Australia/Oceania	600 000	270 000	105 000
Europe	3 150 000	1 225 000	800 000
North & Central America	6 000 000	1 500 000	1 100 000
South America	7 400 000	2 600 000	2 300 000
World	40 150 000	14 060 000	8 905 000
Turkey	433 000	216 000	129 900
Turkey/World	1.07	1.54	1.84

Table 5
Turkey's annual hydropower potential according to DSI and new criteria [13,14]

Basin	Average annual current (Billion m^3)	Gross potential (GW h)	Potential according to DSI		Potential according to new criteria	
			Economically feasibility potential (GW h)	Installed power (MW)	Economically feasibility potential (GW h)	Installed power (MW)
Fırat (Euphrates)	31.61	84 122	39 375	10 345	46 267	12 176
Dicle (Tigris)	21.33	48 706	17 375	5416	24 353	7610
Eastern Black Sea	14.90	48 478	11 474	3257	24 239	6925
Eastern Mediterranean	11.07	27 445	5216	1490	10 978	3137
Antalya	11.06	23 079	5355	1537	9232	2638
Çoruh	6.30	22 601	10 933	3361	12 431	3825
Ceyhan	7.18	22 163	4825	1515	8865	2860
Seyhan	8.01	20 875	7853	2146	9394	2609
Kızılırmak	6.48	19 552	6555	2245	7821	2697
Yeşilırmak	5.80	18 685	5494	1350	8408	2213
Western Black Sea	9.93	17 914	2257	669	7166	2108
Western Mediterranean	8.93	13 595	2628	723	5438	1511
Aras	4.63	13 114	2372	631	5246	1418
Sakarya	6.40	11 335	2461	1175	3967	1984
Susurluk	5.43	10 573	1662	544	2643	881
Others		30 744	1788	546	1721	507
Total	186.05	432 981	127 623	36 950	188 169	55 099

meeting about 30.6% of the electricity demand in 2004. Hydro plants with an installed capacity of 3197 MW and an annual generation capacity of 10 518 GW h, which is almost 8% of the total potential, are under construction [15]. In the future, 565 more hydropower plants will be constructed to exploit the remaining potential of 73 459 GW h/yr, bringing the total number of hydropower plants to 565 with a total installed capacity of 20 667 MW. Those are being designed are divided into four sub-groups and distribution of Turkey hydro power potential according to design level are given in Table 6. As follows this table: 10 752 GW h/yr (8.3%) with final design ready, 26 562 GW h/yr (20.4%) with feasibility report ready, 17 819 GW h/yr (13.7%) with master plan ready, and 18 326 GW h/yr (14.1%) with preliminary report ready.

Small hydropower is in most cases "run-of-river"; in other words any dam or hydraulic structure is quite small, usually just a weir, and generally little or no water is stored. The civil works purely serve the function of regulating the level of the water at the intake to the hydropower plant. Therefore run-of-river installations do not have the same kinds of adverse effect on the local environment as large hydro. On the other hand, hydropower has various degrees of "smallness". To date, there is still no internationally agreed definition of "small" hydro; the upper limit varies between 2.5 and 25 MW. A maximum of 10 MW is the most widely accepted value worldwide, although the definition in China stands officially at 25 MW. In Turkey, the upper limit is accepted as 50 MW [16]. While the distribution of the hydropower plants, which are under design level, is presented in

Table 6
Distribution of Turkey hydropower potential according to design level (February 2006) [15]

Status of hydroelectric plants projects	Number of project	Installed capacity (MW)	Total annual hydroelectric energy generation				
			Reliable energy (GW h)	Total energy (GW h)	Ratio (%)	Cumulative energy (GW h)	Ratio (%)
In operation	142	12 788	33 560	45 930	35.4	45 930	35.4
Under construction	40	3197	6358	10 518	8.1	56 448	43.5
Planned	565	20 667	40 006	73 459	56.5		
Final design ready	14	3556	7089	10 752	8.3	67 200	51.8
Feasibility report ready	175	7306	13 305	26 562	20.4	93 762	72.2
Master plan ready	96	5120	10 582	17 819	13.7	111 581	85.9
Preliminary report ready	280	4685	9030	18 326	14.1	129 907	100.0
Total potential	747	36 652	79 924	129 907	100.0	129 907	100.0

Table 7
Distribution of under design hydropower plants according to their hydro capacity [15]

Classification (MW)	Number of HEPP	Total capacity (MW)	Total reliable energy (GW h/yr)	Average annual energy (GW h/yr)	Percentage of total annual energy
<10	278	1086	1552	4940	6.72
10–50	188	4691	9038	18 847	25.66
>50	99	14 890	29 415	49 672	67.62
Total	565	20 667	40 006	73 459	100.00

Table 8
Distribution of existing hydro power plants according to their hydro capacity [17]

Classification (MW)	Number of HEPP	Total capacity (MW)	Total reliable energy (GW h/yr)	Average annual energy (TW h/yr)	Percentage of total annual energy
<10	72	172.95	277.00	675.28	1.47
10–50	32	734.86	1259.80	2758.00	6.00
>50	38	11880.40	32023.00	42497.00	92.53
Total	142	12788.21	33559.80	45930.28	100.00

Table 7. According to their hydro capacity, the distribution of the existing hydropower plants is given Table 8. As can be seen these tables, there is 72 installed small hydropower plants (SHPs), which have 172.95 MW of installed capacity [17], and it is also planned to allocate 278 SHPs with 1086 MW of capacity in Turkey. Thus, when this planned power plants are in operation, the SHP will able to meet 4.7% of total annual energy (present is 1.47% of the total).

3.2. Geothermal energy

Geothermal energy is the energy contained as heat in the Earth's interior. The origin of this heat is linked with the internal structure of our planet and the physical processes occurring there. This heat is brought to the near-surface by thermal conduction and by intrusion into the Earth's crust of molten magma originating from great depths. Groundwater is heated to form hydrothermal resources. Use of hydrothermal energy is economic today at a number of high-grade sites. Hydrothermal resources are tapped by existing well-drilling and energy-conversion technologies to generate electricity or to produce hot water for direct use (house heating, washing, etc.). For generation of electricity, hot water at temperatures ranging from about 150 to 370 °C is brought from the underground reservoir to the surface through production wells and is flashed to steam in special vessels by release of pressure. The steam is separated from the liquid and fed to a turbine engine, which turns a generator [18].

Geothermal energy includes direct uses of heat, electricity production, and geothermal heat pump. Direct applications of geothermal energy can involve a wide variety of end uses, such as space heating and cooling, industry, greenhouses, fish farming, and health spas. The technology, reliability, economics, and environmental acceptability of direst use of geothermal energy have been demonstrated throughout the world.

Turkey has an important place among the richest countries (the first in Europe, seventh in the world) in geothermal potential. Around 1000 hot and mineralized natural self-flowing springs exist in Turkey. The geothermal resources in Turkey can be classified into three groups: low temperature fields (<70 °C), moderate temperature fields (70–150 °C), and high temperature fields (more than 170 °C). Although they exist all over the country, most of them lie in the Western, North-Western, and Middle Anatolia. The temperature limit is accepted to be 20 °C for balneological purposes. With the exception this, there are 170 geothermal fields with a temperature over 35 °C in Turkey–Aydın–Germencik (232 °C), Denizli–Kızıldere (242 °C), Çanakkale–Tuzla (173 °C), and Aydın–Salavatlı (171 °C) fields—that are suitable for electricity generation. Depending on the use of new technologies, the Manisa–Salihli–Caferbeyli (155 °C), Kütahya–Simav (162 °C), Izmir–Seferihisar (153 °C), Dikili (130 °C), and Denizli–Gölemezli (under search) fields, that the locations of these geothermal areas are illustrated in Fig. 1, can be used in electricity generation and the others are suitable for direct use [19].

In 2005, geothermal energy use of Turkey amounted to about 119.7 GW h/yr of electricity and 6900.5 GW h/yr for direct use. Data accumulated since 1962 show that there may be existed about 4500 MW of geothermal energy usable for electrical power generation in high enthalpy zones [20]. A recent estimate of the geothermal potential of Turkey, gives the total potential resources for direct use in excess of 31 500 MW_t. These figures for the potential cover both known and unidentified resources. Proven, probable and possible potential of Turkey are given in Table 9. It is estimated the identified geothermal resources to be 200 MW_e for electricity generation (resource temperature in excess of 473 K) and in excess of 3293 MW_t heat for direct use (resource temperature lower than 473 K).

Table 10 shows capacity in geothermal utilization in Turkey. Most of the development in the direct use has been in district heating, which now serves 103 000 residences (827 MW_t and 7712.7 TJ/yr), and in individual space heating (74 MW_t and 816.8 TJ/yr). A total of 800 000 m^2 of greenhouses are heated by geothermal fluids (192 MW_t and 3633 TJ/yr).

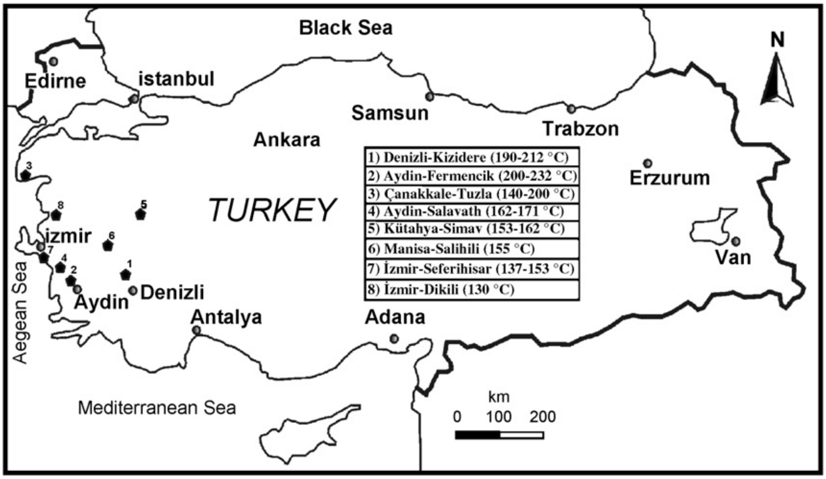

Fig. 1. Map indicating Turkey's geothermal fields suitable for electricity generation.

Table 9
Status of Turkey's geothermal energy in 2005 [21–23]

		Proven potential	Probable and possible potential	
Heating (<473 K)		3293 MW_t		31 500 MW_t
Electricity (>473 K)		200 MW_e		4500 MW_e
	Capacity (MW_t)	Use (TJ/yr)	Use GW h/yr	Capacity factor
Direct use	1495	24 839.9	6900.5	0.53
Electricity	20.4		119.73	

Table 10
Capacity in geothermal utilization in Turkey [24]

Geothermal utilization	Capacity
District heating	827 MW_t
Balneological utilization	402 MW_t
Total direct use	1229 MW_t
Carbon dioxide production	120 000 t/yr
Power production	20 MW_e (Denizli–Kızıldere) (operating) 25 MW_e (Germencik) (under construction) 10 MW_e (Aydın Salavatlı) (under construction)

Geothermal heated pools used for bathing and swimming account for a capacity of 402 MW_t and utilize 12 677.4 TJ/yr. About 120 000 ton of liquid carbon dioxide and dry ice are produced annually at the Kızıldere power plant. By the year 2010 Turkey aims at

having 500 MW_e dedicated to electricity generation and 3500 MW_t for space heating. Heat pumps are not being used at present, because of the high cost of electricity [21–24].

It is clear that the present use of geothermal energy is a very small fraction of the identified geothermal potential. Four percent of geothermal source potential of Turkey is only evaluated up to 2005. When Turkey uses all of the total geothermal potential it can meet 12.7% of the total energy need (heat + electricity) from geothermal energy. There is certainly space for an accelerated use of geothermal energy both for electricity generation and direct use in the near future [25].

3.3. Biomass energy

Biomass is the term used for all organic material originating from plants (including algae), trees and crops and is essentially the collection and storage of the sun's energy through photosynthesis. Biomass energy, or bioenergy, is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels.

Biomass for bioenergy comes either directly from the land, as dedicated energy crops, or from residues generated in the processing of crops for food or other products such as pulp and paper from the wood industry. Another important contribution is from post consumer residue streams such as construction and demolition wood, pallets used in transportation, and the clean fraction of municipal solid waste (MSW). The biomass to bioenergy system can be considered as the management of flow of solar generated materials, food, and fiber in our society. These inter-relationships are shown in Fig. 2, which presents the various resource types and applications, showing the flow of their harvest and residues to

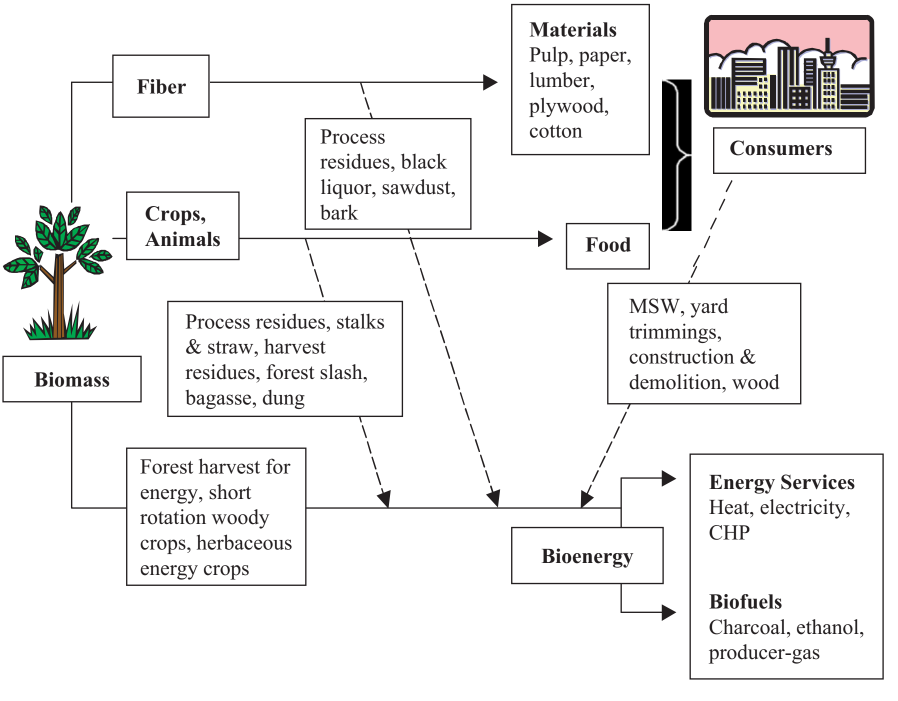

Fig. 2. Biomass and bioenergy flow chart [26].

bioenergy applications. Not all biomass is directly used to produce energy but rather it can be converted into intermediate energy carriers called biofuels. This includes charcoal (higher energy density solid fuel), ethanol (liquid fuel), or producer-gas (from gasification of biomass) [26].

Biomass is the oldest form of renewable energy exploited by mankind, mainly in the form of wood burnt to provide heat and light for domestic and productive activities. The main biomass resources are agricultural residues and wastes (straw, animal manure, etc.), organic fractions of municipal solid waste and refuse, sewage sludge, industrial residues (e.g., from the food and paper industries), short-rotation forests (willow, poplar, eucalyptus), herbaceous lingo-cellulosic crops (miscanthus), sugar crops (sugar beet, sweet sorghum, Jerusalem artichoke), starch crops (maize, wheat), oil crops (rape seed, sunflower), wood wastes (forest residues, wood processing waste, construction residues). In the long term, energy crops could be a very important biomass fuel source. At present, however, wastes (wood, agricultural, municipal or industrial) are the major biomass sources [27]. Table 11 represents status of biomass energy in Turkey. As shown in Table 11, Turkey utilizes biomass energy for heating purpose mostly [28,29].

Direct burning in Turkey for many years has used fuelwood, animal wastes, agricultural crop residues, and logging wastes. These sources are often called non-commercial energy sources, but in Turkey, fuelwood is a tradable community since it is the primary fuel in rural and urban poor districts. Fuelwood is the fourth largest source of energy in Turkey. Wood is the major source of energy in rural Turkey. An average consumer in a year burns $0.75\,m^3$ fuelwood. The total forests potential of Turkey is around 935 million m^3 with an annual growth of about 28 million m^3. The total forest area in Turkey occupies 26% of the country's territory. Traditional fuels predominate in rural areas; almost all biomass energy is consumed in the household sector for heating, cleaning, and cooking needs of rural people. The lumber, pulp and paper industries burn their own wood wastes in large furnaces and boilers to supply 60% of the energy needed to run factories. In their homes, Turkish people burn wood in stoves and fireplaces to cook meals and warm their residences. Wood is the primary heating fuel in 6.5 million homes in Turkey [30].

Biogas energy is also derived from biomass, which is combusted as a gas comprising primarily methane, the most common constituent of natural gas. Biogas is commonly generated from biomass waste products at sewage treatment plants, solid waste landfills, through forest sector activities, and agricultural operations. Biogas can be produced through a biological process that "digests" the biomass in a chamber with no oxygen, through a chemical process, or through heating in the absence of oxygen. The biomass products are converted to a gaseous fuel. Biogas is then combusted in a boiler to produce steam for power generation through a steam turbine or through a combustion turbine directly. In both instances, under cogeneration applications, the residual heat is used as energy for other applications. In the coming years, these energy sources will play an increasingly significant role for producing green power [31]. Biogas production potential in Turkey has been estimated at 1.5–2 Mtoe but only two small units (in total 5 MW) are in operation and one new facility (1 MW) has been licensed [6]. Around 85% of the total biogas potential is from dung gas, while the remainder comes from landfill gas. The dung gas potential is obtained from 50% sheep, 43% cattle and 7% poultry (Table 12). The use of animal wastes as biofuel is limited because they are mostly used in agriculture as fertilizers.

Table 11
Status of biomass energy in Turkey [28,29]

	1999	2000	2002	2003	2004
Production of total energy from biomass (TJ)	301 722	272 732	251 924	241 929	232 688
Production of electricity from biomass (GW h)	–	220	174	116	104
Production of heat from biomass (GW h)	83 818.37	75 544.95	69 810.49	67 091.88	64 536.73
Net generating capacity (MW)					
Industrial waste	–	19	19	19	
Municipal solid waste	–	–	–	–	
Solid waste	–	72	72	72	
Gas from biomass	–	4	9	9	
Comb. renewable non-specified	–	–	–	–	
Total biomass	–	95	100	100	
Total electricity (GW h)					
Industrial waste	–	54	45	36	28
Municipal solid waste	–	–	–	–	–
Solid waste	–	145	103	48	46
Gas from biomass	–	21	26	32	30
Comb. renewable non-specified	–	–	–	–	–
Total biomass	–	220	174	116	104
Electricity only plants (GW h)					
Industrial waste	–	38	32	24	
Municipal solid waste	–	–	–	–	
Solid biomass	–	–	–	–	
Gas from biomass	–	–	3	7	
Comb. renewable non-specified	–	–	–	–	
Total biomass	–	38	35	31	
Combined heat and power (CHP) *plants* (GW h)					
Industrial waste	–	16	13	12	
Municipal solid waste	–	–	–	–	
Solid biomass	–	145	103	48	
Gas from biomass	–	21	23	25	
Comb. renewable non-specified	–	–	–	–	
Total biomass	–	182	139	85	

Table 12
Distribution of biogas potential of Turkey [32]

	Biogas potential (million m^3/yr)
Dung gas	3302.85
Cattle (43.103 Mt dung)	1422.39
Sheep (28.303 Mt dung)	1641.58
Poultry (3.063 Mt dung)	238.88
Landfill gas	600.00
Total biogas*	3902.85

*Provided that all dung is used for biogas production.

3.4. Solar energy

There are two basic categories of technologies that convert sunlight into useful forms of energy, aside from biomass-based systems that do this in a broader sense by using photosynthesis from plants as an intermediate step. First, solar photovoltaic (PV) modules convert sunlight directly into electricity. Second, solar thermal power systems use focused solar radiation to produce steam, which is then used to turn a turbine producing electricity [26].

PV solar energy conversion is the direct conversion of sunlight into electricity. This can be done by flat plate and concentrator systems. An essential component of these systems is the solar cell, in which the PV effect—the generation of free electrons using the energy of light particles—takes place. These electrons are used to generate electricity.

Solar radiation is available at any location on the surface of the Earth. It can produce high-temperature heat, which can generate electricity. The most important solar thermal technologies to produce electricity-concentrating use direct irradiation. Low cloud areas with little scattered radiation, such as deserts, are considered most suitable for direct-beam-only collectors. Thus the primary market for concentrating solar thermal electric technologies is in sunnier regions, particularly in warm temperate, sub-tropical, or desert areas.

The easiest and most direct application of solar energy is the direct conversion of sunlight into low-temperature heat-up to a temperature of 100 °C. In general, two classes of technologies can be distinguishes: passive and active solar energy conversion. With active conversion there is always a solar collector, and the heat is transported to the process by a medium. With passive conversion the conversion takes place in the process, so no active components are used. The best known active conversion application is the solar domestic hot water system. Another technology in the building sector is the solar space heating system. Such a system can be sized for single houses or for collective buildings and district heating. Similar technologies can be applied in the industrial and agricultural sector for low-temperature heating and drying applications. Heating using solar energy can also be achieved by heat pumps [8].

An important part of Turkey is suitable for utilization of solar energy. Turkey is between the 36° and 42° north latitudes. The solar energy potential of Turkey is the equivalent of 1.3 billion tonnes of oil. The solar thermal capacity is approximately 2640 h/yr and annual solar intensity is 3.6 kW h/m^2 day. This is sufficient to provide adequate energy for solar thermal applications [32,33]. The solar radiation and sunshine duration vary between about 240–395 cal/cm^2 day and 4.5–8.5 h/day, respectively. Solar energy potential is given in Table 13. The average solar radiation is 309.6 cal/m^2 day and the average sunshine duration is 7.2 h/day. The south-eastern Anatolia and Mediterranean regions are very suitable for solar energy use.

There are basically three types of collectors: flat-plate, evacuated-tube, and concentrating. Flat-plate collectors are the most commonly used types. Flat-plate solar collectors used for domestic water heating are widely used and commercially available in Turkey. In 2003, the collector surface area installed in Turkey was 10 million m^2, including both household systems and large-scale use in hotels, industrial activities, etc. Using these collectors for heating contributed 0.35 Mtoe to energy production. Annual collector manufacturing capacity is 1 million m^2. The Electrical Power Resources Survey and Development Administration (EIE) installed a computer-aided test stand in order to

Table 13
Solar energy potential by region [6,33]

Region	Solar radiation (cal/cm^2 day)	Total solar energy (kW h/m^2 yr)	Sunshine duration	
			(h/day)	(h/yr)
Southeast Anatolia	344.8	1460	8.2	2993
Mediterranean	328.3	1390	8.1	2956
East Anatolia	322.4	1365	7.3	2664
Central Anatolia	310.3	1314	7.2	2628
Aegean	308.0	1304	7.5	2738
Marmara	275.9	1168	6.6	2409
Black Sea	264.5	1120	5.4	1971
Turkey average	309.6		7.2	

enable the manufacturers to improve the quality and efficiency of the collectors. It used the test stand to help the Turkish Standard Institute to develop new standards for collectors. The EIE has also developed a parabolic solar cooker and has studied the possibility to use vacuum tube solar collectors in heating and cooling [6].

PVs are one of the fastest growing solar energy technologies. PV devices, commonly called solar cells or modules, use semiconductor material to directly convert sunlight into electricity [34]. In the area of PVs, in Turkey, the EIE has implemented some small-scale stand-alone systems but also one grid-connected project. In order to investigate the operational properties of PV systems, one stand-alone 1.6 kW peak (kW p) PV system for power generation was installed already in 1985. A 4.8 kW p grid-connected PV system is installed in Didim Training and Research Centre to gain experience about the operating problems of grid-connected systems. Another 1.2 kW p grid-connected PV system was installed in Ankara in 2002 [6].

3.5. *Wind energy*

Wind energy, like most terrestrial energy sources, comes from solar energy. Solar radiation emitted by the sun travels through space and strikes the Earth, causing regions of unequal heating over land masses and oceans. This unequal heating produces regions of high and low pressure, creating pressure gradients between these regions. The second law of thermodynamics requires that these gradients be minimized-nature seeks the lowest energy state in order to maximize entropy. This is accomplished by the movement of air from regions of high pressure to regions of low pressure, what it is known as wind. Large-scale winds are caused by the fact that the Earth's surface is heated to a greater degree at the equator than at the poles.

Prevailing winds combine with local factors, such as the presence of hills, mountains, trees, buildings, and bodies of water, to determine the particular characteristics of the wind in a specific location. Because air has mass, moving air in the form of wind carries with it kinetic energy. A wind turbine converts this kinetic energy into electricity. The energy content of a particular volume of wind is proportional to the square of its velocity. Thus, a doubling of the speed with which this volume of air passes through a wind turbine will result in roughly a four-fold increase in power that can be extracted from this air.

In addition, this doubling of wind speed will allow twice the volume of air to pass through the turbine in a given amount of time, resulting in an eight-fold increase in power generated. This means that only a slight increase in wind velocity can yield significant gains in power production [35].

Turkey has a land surface area of officially 774 815 km^2 [36]. Surrounded by mountains, its unique geographical character creates a regular and moderate air inflow through its mountainous straits and passages. Its location between the colder European and warmer Asian and African systems also causes a wide variety of temperature and climate difference [37]. All the land area of Turkey is not suitable for the installation of turbines due to a topographic structure. Based on the examination of the wind atlas may be concluded that the regions of Aegean, Marmara, and East-Mediterranean have high wind energy potential. Turkey's total theoretically available potential for wind power is calculated to be around 88 000 MW annually. It is also estimated that Turkey has an economically wind power potential of about 10 000 MW_e [36]. Turkey has the highest share with 166 TW/yr in technical wind energy potential between European countries [38].

Annual average wind speed and annual average wind energy potential of various regions of Turkey are shown in Table 14. The annual average wind speeds range from a low of 2.1 m/s in the East Anatolia region to a high of 3.3 m/s in the Marmara region. The most attractive regions for wind energy applications are the Marmara, the southeast Anatolian, and the Aegean regions. These regions are highly suitable for wind power generation, since the wind speed exceeds 3 m/s in most of these areas [38].

In Turkey, wind energy use has been focusing on grid-connected systems. At present, total installed wind power capacity is 20.1 MW; in two power plants in İzmir, with 1.5 and

Table 14
Wind potential of various regions of Turkey [38]

Region	Annual average wind density (W/m^2)	Annual average wind speed (m/s)
Marmara	51.9	3.3
Southeast Anatolia	29.3	2.7
Aegean	23.5	2.6
Mediterranean	21.4	2.5
Black Sea	21.3	2.4
Central Anatolia	20.1	2.5
East Anatolia	13.2	2.1
Turkey average	24.0	2.5

Table 15
Installed wind energy plants in Turkey [39]

Location of plants	Date of commissioned	Number of turbine	Installed capacity (MW)
İzmir–Çeşme–Germiyan	1998	3	1.5
İzmir–Çeşme–Alaçatı	1998	12	7.2
Çanakkale–Bozcaada	2000	17	10.2
İstanbul–Hadimköy	2003	2	1.2
Total		34	20.1

7.2 MW installed capacity; one in Çanakkale, with an installed capacity of 10.2 MW; and one in İstanbul, with an installed capacity of 1.2 MW (Table 15) [39].

4. Greenhouse gas emissions in Turkey

Greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are very efficient in absorbing the infrared heat radiation emitted from Earth's warm surface while transparent to visible light. They trap the radiation heat in the atmosphere and then reemit it back toward the Earth. The heat balance called greenhouse effect is essential to life on Earth. Anthropogenic emissions of GHGs, however, led to a considerable increase in the concentrations of these gases in the atmosphere since the Industrial Revolution. Thus, it is expected to trigger global warning, which may cause adverse environmental disasters. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was declared in Rio De Janerio, followed by the Kyoto Protocol in 1997 [40]. Subsequently, developed and developing countries around the world have prevailingly addressed the mitigation strategies and policies relating to the GHGs. It is also well known that the emissions of GHGs are closely related to the use of energy [41].

Greenhouse gas emissions of Turkey have been estimated by State Institute of Statistics (DIE) and the Intergovernmental Panel on Climate Change (IPCC) guideline has been used in calculations. IPCC Guidelines define carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as direct GHGs and nitrogen oxides (NO_x), carbon monoxides (CO), non-methane volatile organic compound (NMVOC), hydro-fluoro carbons (HFCs), per-fluoro-carbons (PFCs), sulphur hexafluoride (SF_6) and sulphur dioxide (SO_2) as indirect greenhouse gases. CO_2 emissions having special situation among all greenhouse gases are generated from fuel consumption and industrial processes. CO_2 emissions generated from fuel consumption by sectors were studied, in 2005 43% was generated from energy and transformation sector, 24% from industrial sector, 18% from transportation sector and 15% from other sectors (residential, agriculture, commercial and forest). The estimation for the year of 2010 shows that the ratio of energy and transformation sector will increased to 46% and the ratio of industrial sectors will be 27%, transportation sector will be 16% and other sectors will be 11% [42].

Table 16 shows direct and indirect GHG emissions, calculated by using IPCC guideline, in Turkey by source between 1990 and 2010. As can be seen this table, most important matter for CH_4 emissions, while CH_4 emissions generated by livestock decreased from 60.21% to 59.95% according to the year of 2005 in 2010, the ratio of CH_4 emission generated from fuel consumption will increase from 13.86% to 14.23% in 2010 according to the year of 2005. N_2O emissions was evaluated according to the contribution of N_2O emissions to the total direct GHG emissions, while the ratio of N_2O emissions generated from fuel consumption was 28% in 2005, this ratio will increase to 35% in 2010. On the other hand, the ratio of N_2O emissions generated from industrial processes was 70% in 2005 but this ratio will be estimated to decrease to 63% in 2010.

Turkey's carbon emissions have risen in line with the country's energy consumption. Since 1980, Turkey's energy-related carbon emissions have jumped from 71.6 Mt annually to 202.9 Mt in 2003. Emissions grew by 4.8% compared to 2002 levels and by just over 57.5% compared to 1990 levels. Oil has historically been the most important source of emissions, followed by coal and gas. However, in 2003, oil represented 39.6% of total emissions, while coal represented 40.1% and gas 20.3% (Table 17). The contribution of

Table 16
Direct and indirect greenhouse gas emissions by sources between 1990 and 2010 (%) [42]

Emissions	Years				
	1990	1995	2000	2005	2010
CO_2 *emission fractions*					
Fuel consumption	80	80	84	88	91
Energy and transformation sectors	36	36	39	43	46
Industry	26	25	21	24	27
Transportation	19	20	21	18	16
Other	19	19	19	15	11
Industrial processes	20	20	16	12	9
CH_4 *emission fractions*					
Fuel consumption	14.54	11.68	14.04	13.86	14.23
Coal mining	2.02	3.38	3.26	3.27	3.25
Transportation of crude oil	0.001	0.001	0.001	0.001	0.001
Refined oil	0.01	0.01	0.01	0.01	0.01
Industrial processes	0.23	0.19	3.26	0.19	0.19
Rice cultivation	2.22	2.22	2.26	2.26	2.25
Livestock	78.87	67.53	60.08	60.21	59.95
Burning of agricultural residues	2.10	1.73	1.74	1.74	1.74
Landfills	–	13.25	18.43	18.47	18.39
N_2O *emission fractions*					
Fuel consumption	77	15	25	28	35
Industrial processes	11	83	73	70	63
Burning of agricultural residues	12	2	3	3	2
NO_x *emission fractions*					
Fuel consumption	96.83	96.55	97.46	98.06	98.59
Industrial processes	1.65	2.27	1.66	1.27	0.93
Burning of agricultural residues	1.51	1.18	0.87	0.67	0.49
CO *emission fractions*					
Fuel consumption	86.35	87.91	93.95	94.69	95.55
Industrial processes	1.59	1.56	0.78	0.68	0.57
Burning of agricultural residues	12.06	10.53	5.27	4.63	3.88
NMVOC emission fractions					
Fuel consumption	91.53	91.54	96.00	96.50	97.20
Industrial processes	8.47	8.46	4.00	3.50	2.80
SO_2 *emission fractions*					
Fuel consumption	92	92	91	92	92
Industrial processes	8	8	9	8	8

each fuel has, however, changed significantly owing to the increasingly important role of gas in the country's fuel mix starting from the mid-1980s [43].

In 2003, manufacturing industries and construction were the largest contributors of CO_2 emissions, accounting for 28.2% of the country's total. Public electricity and heat production was the second largest, representing 26.3% of total emissions, followed by transport, which represented 17.7% and other sectors with 16.4%. Unallocated autoproducers sector, account for 8.1% of total emissions (Fig. 3).

Table 17
CO_2 emissions by fuel* (million tonnes of CO_2) [43]

	Years									% Change 1990–2003 (%)
	1975	1980	1985	1990	1995	2000	2001	2002	2003	
Coal	20.7	27.1	45.2	58.9	62.4	90.9	75.8	77.7	81.4	38.1
Oil	39.0	44.6	50.0	63.3	80.0	83.9	78.2	81.8	80.3	26.9
Gas	–	–	0.1	6.5	13.0	28.9	31.1	34.1	41.1	528.4
Total	59.6	71.6	95.3	128.8	155.4	203.7	185.2	193.6	202.9	57.5

*Estimated using the IPCC sectoral approach.

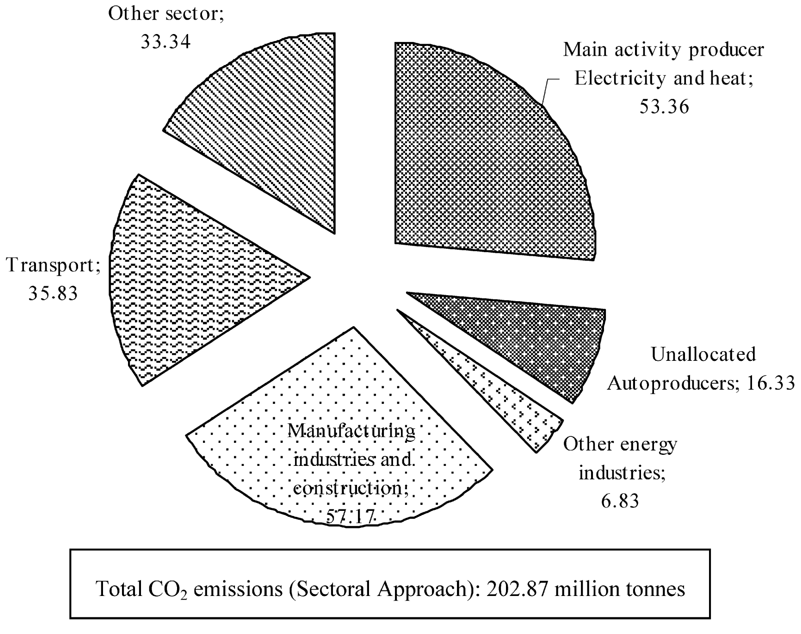

Fig. 3. 2003 CO_2 emissions by sector in Turkey.

Turkey is not yet a party to the UN Framework Convention on Climate Change or the Kyoto Protocol, meaning the country has no binding requirements to cut carbon emissions by the 2008–2012 period as most other IEA countries have. However, Turkey has established a National Climate Coordination Group (NCCG) to carry out the national studies in line with those conducted by all countries of the UNFCC. Armed with the research of the NCCG and with studies underway for a National Climate Programme, Turkey is considering accession to the Kyoto Protocol. Additional pressure to meet EU standards make it increasingly likely that Turkey will accept some level of binding emission reduction requirements in the foreseeable future [44].

As Turkey resumes economic growth in coming years and attempts to meet EU membership criteria, it will increasingly need to take environmental considerations into account. Improved energy efficiency is a key to this strategy, with reduction of state energy subsidies allowing energy prices to more accurately reflect true costs. Overall, Turkey's energy demand is expected to increase by 2.9% annually through 2020, while carbon emissions grow by a somewhat slower 2.2% yearly rate, as natural gas and renewables (which emit no carbon) consumption grows faster than coal usage. To the extent that natural gas and renewables replace more carbon-intensive fuels, the country's increased use of natural gas will further diversify the Turkish energy supply and contribute to the mitigation of urban pollution and CO_2 emissions. By setting differentiated taxes to promote the use of cleaner fuels (and, in particular, to promote the use of low-sulphur heavy fuel oil), Turkey can significantly stem the rising tide of carbon emissions and other pollutants [45].

5. Environmental effects of renewable energy sources

Environmental impacts that resources used in energy generation have occurred during production are shown in Table 18. In table, it is used "+" in case of being stated impact of source. It is used "–" in the event of not being or little being stated impact of source. It is examined whether or not there is only an impact of source. Therefore, marks in the table are relative [46].

5.1. Hydropower

Hydropower dams can cause several environmental problems, even though they burn no fuel. Damming rivers may destroy or disrupt wildlife and natural resources. Fish, for one, may no longer be able to swim upstream. Damming a river can alter the amount and quality of water in the river downstream of the dam, as well as preventing fish from migrating upstream to spawn. These impacts can be reduced by requiring minimum flows downstream of a dam, and by creating fish ladders which allow fish to move upstream past the dam [47]. Hydro plant operations may also affect water quality by churning up dissolved metals that may have been deposited by industry long ago. Hydropower operations may increase silting, change water temperatures, and lower the levels of

Table 18
Environmental impacts as source type [46]

Source	Contribution into emissions, air pollution, and climate change	Contribution into water pollution and watery areas	Waste	Visual impacts	Noise	Impacts on habitat and living life
Fossil fuels	+	+	+	–	+	+
Solar	–	–	–	+	–	–
Wind	–	–	–	+	+	+
Geothermal	–	+	–	–	+	+
Hydrogen	–	+	–	–	–	–
Ocean-wave	–	+	–	+	+	+
Biomass	+	–	+	+	–	+

dissolved oxygen. Some of these problems can be managed by constructing fish ladders, dredging the silt, and carefully regulating plant operations.

Hydropower has advantages, too. Hydropower's fuel supply (flowing water) is clean and is renewed yearly by snow and rainfall. Furthermore, hydro plants do not emit pollutants into the air because they burn no fuel. With growing concern over greenhouse gas emissions and increased demand for electricity, hydropower may become more important in the future. Hydropower facilities offer a range of additional benefits. Many dams are used to control flooding and regulate water supply, and reservoirs provide lakes for recreational purposes, such as boating and fishing [48].

The most obvious impact of hydroelectric dams is the flooding of vast areas of land, much of it previously forested or used for agriculture. The size of reservoirs created can be extremely large. Reservoirs can be used for ensuring adequate water supplies, providing irrigation, and recreation; but in several cases they have flooded the homelands of native peoples, whose way of life has then been destroyed. Many rare ecosystems are also threatened by hydroelectric development [47].

Finally, a dam produces impacts on the river ecosystems that affect the fauna and the flora in the river region. In the dam area, the following impacts can occur: loss of habitats and biodiversity; loss of aquatic vegetation; decrease of water quality; loss of fish communities; alteration of the landscape; accumulation of sediments in the reservoir and organic material accumulation. In down- and up-river areas, the following impacts can occur: habitat fragmentation; decrease of water quality; obstruction of the fishes migratory movements; organic material transport; sediments transports; seasonal fluctuations of the water column and daily fluctuations of the water column [49].

5.2. Geothermal energy

Geothermal fluids contain a variable quantity of gas—largely nitrogen and carbon dioxide with some hydrogen sulphide and smaller proportions of ammonia, mercury, radon, and boron. The amounts depend on the geological conditions of different fields. Most of the chemicals are concentrated in the disposal water, routinely re-injected into drill holes, and thus not released into the environment. The concentrations of the gases are usually not harmful, and the removal of such gases as hydrogen sulphide from geothermal steam is a routine matter in geothermal power stations where the gas content is high. The range in carbon dioxide emissions from high-temperature geothermal fields used for electricity production in the world is 13–380 g kW h, less than for fossil fuel power stations. Sulphur emissions are also significantly less for geothermal than fossil fuel electric power stations.

The gas emissions from low-temperature geothermal resources are normally only a fraction of the emissions from the high-temperature fields used for electricity production. The carbon dioxide content is lower than that of the cold groundwater. In sedimentary basins, the gas content may be too high to be released. In such cases the geothermal fluid is kept at pressure within a closed circuit (the geothermal doublet) and re-injected into the reservoir without any degassing. Conventional geothermal schemes in sedimentary basins commonly produce brines that are generally re-injected into the reservoir and thus never released into the environment. The carbon dioxide emission from these is thus zero [8]. In addition, geothermal power plants require relatively little land, taking up only a fraction of that needed by other energy sources. Other land uses can mingle with

geothermal plants with little interference or fear of accidents. Geothermal facilities have neither huge piles of ash, nor slag, nor bags of radiation-tainted sulphur to contend with. Containment barriers associated with most fossil-fuelled power plants are non-existent in current designs [50].

Discharge of wastewater is also a potential source of chemical pollution. Spent geothermal fluids with high concentrations of chemicals such as boron, fluoride or arsenic should be treated, and/or re-injected into the reservoir. However, the low-to-moderate temperature geothermal fluids used in most direct-use applications generally contain low levels of chemicals and the discharge of spent geothermal fluids is seldom a major problem. Sometimes these fluids can be discharged into surface water after cooling. The water can then be cooled in special storage ponds or tanks to avoid modifying the ecosystems of natural bodies of water.

Geothermal plants produce noise pollution during construction, e.g. by drilling of wells and the escape of high-pressure steam during testing. Noise is usually negligible during operation with direct-heat applications. However, electricity generation plants produce some noise from the cooling tower fans, the steam ejector and the turbine. Geothermal plants are often located in areas of high scenic value, where the appearance of the plant is important. Fortunately, geothermal power plants take up little area and, with careful design they can blend well into the surrounding environment. Wet cooling towers at plants can produce plumes of water vapour, which some people find unsightly. In such cases, air-cooled condensers can be used [27].

5.3. Biomass energy

Several environmental impacts are directly related to biomass energy production and consumption. The first is obviously the environmental benefit of displacing fossil fuel usage and a reduction in any adverse environmental impacts that are caused by fossil fuel consumption. In addition, the use of a fossil fuel and biomass together in certain applications, such as electric power generation with coal and wood or coal and refuse-derived fuel in dual-fuel combustion or cocombustion plants, can result in reduction of undesirable emissions. The substitution of fossil fuels and their derivatives by biomass and biofuels also helps to conserve depletable fossil fuels. Another beneficial environmental impact results from the combined application of waste biomass disposal and energy recovery technologies. Examples are biogas recovery from the treatment of biosolids in municipal wastewater treatment plants by anaerobic digestion, landfill gas recovery from municipal solid waste landfills etc. [51].

In terms of air pollutants, biomass feedstocks can offer improvements relative to fossil fuels. Biomass is naturally low in sulphur and therefore, when burned, generates low SO_2 emissions. However, if burned in the open air, some biomass feedstocks would emit relatively high levels of NO_x (given the high nitrogen content of plant material), CO, and particulates. Fortunately, emissions control equipment exists to reduce the amount of each of these pollutants into the atmosphere. Therefore, the air pollution impact of biopower plants will depend upon whether or not facilities have installed devices such as selective catalytic reduction equipment (for NO_x), electrostatic precipitators (for particulates), and catalytic oxidizers (for volatile organic compounds, CO, and NO_x). Finally, some forms biomass may release toxins such as dioxins and heavy metals if the feedstock is contaminated. For instance, organic municipal solid waste could contain inorganic

materials such as plastics. Urban waste wood may not be clean, containing wood that has been treated with resins and varnishes [52].

The abundant use of fertilizers and manure in agriculture has led to considerable environmental problems in various regions: nitrification of groundwater, saturation of soils with phosphate, eutrophication, and unportable water. Phosphates have also increased the heavy metal flux of the soil. But energy farming with short rotation forestry and perennial grasses requires less fertilizer than conventional agriculture. With perennials, better recycling of nutrients is obtained. The leaching of nitrogen for willow cultivation can be a half to a tenth that for food crops, meeting stringent standards for groundwater protection. The use of plantation biomass will result in removal of nutrients from the soil that have to be replenished in one way or the other [8]. The natural humus and dead organic matter in the forest soils is a large reservoir of carbon as well. Conversion of natural ecosystems to managed energy plantations could result in a release of carbon from the soil as a result of the accelerated decay of organic matter [53]. Landscaping and managing biomass production systems can considerably reduce the risks of fire and disease. Thus they deserve more attention in coming projects, policies, and research [8].

The final environmental impact associated with the use of fuel wood is that of land use. Wood energy plantations may displace natural forest ecosystems or land which could be used for food production. Single species "monocultures" of trees do not provide habitat for many other species of plant and animals and are highly susceptible to damage from disease and insects. This may also results in increased use of pesticides in these plantations, with their environmental and health problems [53].

5.4. Solar energy

Solar energy technologies provide obvious environmental advantages in comparison to the conventional energy sources, thus contributing to the sustainable development of human activities. Not counting the depletion of the exhausted natural resources, their main advantage is related to the reduced CO_2 emissions, and, normally, absence of any air emissions or waste products during their operation.

Concerning the environment, the use of solar energy technologies has additional positive implications such as: reduction of the emissions of the greenhouse gases (mainly CO_2, NO_x) and prevention of toxic gas emissions (SO_2, particulates); reclamation of degraded land; reduction of the required transmission lines of the electricity grids; and improvement of the quality of water resources. In regard the socio-economic viewpoint the benefits of the exploitation of solar energy technologies comprise: increase of the regional/national energy independency; provision of significant work opportunities; diversification and security of energy supply; support of the deregulation of energy markets; and acceleration of the rural electrification in developing countries [54].

In environmental terms, PV, like other renewable technologies, can make an important contribution to governmental commitments made at the international summits on climate change. Indeed environmental protection and "green" image are perhaps the main market drivers at the current time. PV has none of the pollutant emissions or environmental safety concerns associated with conventional power generation technologies. A growing number of energy consumers are willing to pay a premium for PV based purely on its environmental added values, while many national governments are increasingly offering incentives to promote the uptake of solar electricity amongst utility customers [55].

5.5. Wind energy

Although wind energy is a clean technology, it is not free of impacts on the environment. Wind energy has a number of special features, including: more than one wind turbine is needed for large-scale production; wind turbines are mainly located in remote and rural areas where the wind resource is present; the turbines may be visible from a great distance; the movement of the blades may draw attention.

As well as these visual impacts, wind energy is associated with other environmental issues such as noise, land use and impacts during the construction phase. Some impacts, such as those on birds and flickering can be measured quantitatively; others, such as visual intrusion and noise require more subjective and qualitative criteria [56]. The primary environmental concerns with wind power are related to potential visual, auditory, locational and wildlife impacts of windfarm installations. However, these concerns can be addressed through proper sitting, public education, and the use of improved technologies.

Some are concerned by the visual impact of wind farms. On land, wind turbines are located where the wind resource is best—typically in highly visible, exposed locations. Offshore wind parks, likewise, are usually situated within sight of the shore. In both cases, the vertical towers and the motion of the rotors cause the wind turbines to become focal points in the landscape for observers close to the wind towers. Fortunately, newer, larger rotors rotate more slowly than their predecessors, and thus are less eye-catching. To further mitigate the visual impact of wind turbines they can be painted to match their surroundings. Some of the wind energy captured by wind turbines is unavoidably transformed into sound energy. Air moving by the rotors generates sound, though improvements in rotor technology have greatly diminished the amount of sound produced in this way. Some sound may also emanate from the gearbox and generator, though sound absorbing materials are used to mitigate this. The apparent noise level of a typical wind farm at 350 m distance varies between 35 and 45 dB. This is similar to the noise level in the reading room of a library. Keep in mind that a wind turbine produces no sound when it is not producing electricity, that is, below the "cut-in" speed. Above this speed, the amount of sound increases as the wind speed increases. Thus, wind farm noise will be partly masked by ambient noise, such as that from the wind rustling leaves or grasses. The sound also tends to be spread out across many frequencies, like white noise, further contributing to its unobtrusiveness. With proper considerations for sound propagation, wind turbines can be sited to have negligible noise impacts.

The environmental benefits of wind power are felt locally, regionally and globally. Wind power can displace power from fossil fuel-powered plants, and thereby help to improve local air quality, mitigate regional effects such as acid rain, and reduce greenhouse gas emissions. Power plants emit pollutants as a by-product of power generation, but also may account for further emissions in connection with plant construction, operation, and decommissioning. For example, the mining and transport of fuel are themselves energy-intensive activities, with associated emissions and environmental impacts. Wind compares favourably to traditional power generation on this metric as well: lifecycle CO_2 emissions per unit of power produced by a wind farm are about 1% of that for coal plants and about 2% of that for natural gas facilities [35].

6. Conclusions

It is well known that the consumption of conventional energy sources resulted in serious environmental pollution problems. Apart from that, fossil fuels are also facing the danger of exhaustion. Turkey should increase the proportion of renewable energy sources in the total energy budget because Turkey is an importing country. On the other hand, domestic fossil fuels are limited and the economical condition of the country is not good. The present study shows that there is an important potential to use renewable energy for Turkey. Especially hydraulic, biomass, geothermal, solar, and wind energy seem to be the most interesting domestic and clean energy sources. Therefore, the use of renewable energy resources shows a promising prospect in Turkey in the future as an alternative to the conventional energy.

Renewable energy technologies have the proven ability to offset increasing emissions of carbon dioxide and other greenhouse gas emissions. For any of these technologies to achieve importance, however, there must be supportive government policy. It must be increased and sustained funding for development of these energy sources.

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